

## Claims

What is claimed is:

- [c1] A tool for radially plastically expanding a pipe having a threaded connection therein, comprising:
- a first section having an increasing diameter and increasing cone angle along a direction of travel through the pipe, the first section comprising a first outer surface adapted to contact an inner surface of the pipe at a plurality of selected contact patches on the first outer surface; and
  - a second section axially disposed behind the first section along the direction of travel, the second section having an increasing diameter and decreasing cone angle along the direction of travel, the second section comprising a second outer surface adapted to contact the inner surface of the pipe at least one selected contact patch on the second outer surface.
- [c2] The tool of claim 1, wherein the first section comprises three contact patches, said three contact patches defining a concave profile of the first outer surface, and wherein the second section comprises two contact patches, said two contact patches defining a convex profile of the second outer surface.
- [c3] The tool of claim 1, wherein the first and second sections comprise a plurality of frustoconical elements.
- [c4] The tool of claim 3, wherein each frustoconical element in the first section has a cone angle and axial length selected so that at most one contact patch is disposed on each frustoconical element in the first section.
- [c5] The tool of claim 1, further comprising a plurality of radial relief grooves on the first and second outer surfaces between said contact patches.

- [c6] The tool of claim 5, wherein at least one of the radial relief grooves comprises an acute angle at a root of said groove.
- [c7] The tool of claim 6, wherein at least one of the radial relief grooves comprises a smooth trough.
- [c8] The tool of claim 1, further comprising a plurality of disks, wherein said selected contact patches are located on said disks.
- [c9] The tool of claim 8, wherein the disks comprise at least two different profiles.
- [c10] The tool of claim 9, further comprising at least one spacer between at least two of said disks.
- [c11] The tool of claim 1, further comprising a plurality of ball bearings on the first and second outer surfaces, wherein said selected contact patches are located on said ball bearings.
- [c12] The tool of claim 11, wherein said ball bearings are arranged helically about at least one of said first outer surface and said second outer surface.
- [c13] The tool of claim 12, wherein said ball bearings are arranged circumferentially about at least one of said first outer surface and said second outer surface.
- [c14] The tool of claim 1, further comprising a plurality of expansion rollers, wherein said contact patches are located on said expansion rollers.
- [c15] The tool of claim 1, wherein the first and second sections comprise a plurality of elements each defining a cone angle, a first element having a cone angle between about 2 and about 6 degrees, an included angle between adjacent segments being between about 174 and about 186 degrees.

- [c16] The tool of claim 1, wherein the first and second sections comprise a plurality of frustoconical elements each defining a cone angle, a change in angle between each element being between about 2 degrees and about 2.5 degrees.
- [c17] A method of expanding casing comprising  
forcing a casing expansion tool through a casing segment, wherein the casing segment has a smaller inside diameter than a largest outside diameter of said expansion tool;  
wherein said expansion tool comprises a first section having an increasing diameter and increasing cone angle along a direction of travel through the casing segment, the first section comprising a first outer surface adapted to contact an inner surface of the casing segment at a plurality of selected contact patches on the first outer surface; and a second section axially disposed behind the first section along the direction of travel, the second section having an increasing diameter and decreasing cone angle along the direction of travel, the second section comprising a second outer surface adapted to contact an inner surface of the pipe at least one selected contact patch on the second outer surface.
- [c18] A tool for radially plastically expanding a pipe having a threaded connection therein, the connection having an engaged thread length  $L_2$ , the tool comprising:  
a first section having an increasing diameter and increasing cone angle along a direction of travel through the pipe, the first section comprising a first outer surface adapted to contact an inner surface of the pipe at a plurality of selected contact patches on the first outer surface; and  
a second section axially disposed behind the first section along the direction of travel, the second section having an increasing diameter and decreasing cone angle along the direction of travel, the second section comprising a

second outer surface adapted to contact the inner surface of the pipe at least one selected contact patch on the second outer surface;  
wherein the first and second section have a length at least about  $L_2$ .

- [c19] The tool of claim 18, wherein the first and second sections further comprise a plurality of expansion segments, and each of said contact patches is located on one of said expansion segments.
- [c20] The tool of claim 19, wherein each of said expansion segments has a length between about  $0.1 \cdot L_2$  and  $L_2$ .
- [c21] The tool of claim 20 wherein each of said expansion segments has a length between about  $0.2 \cdot L_2$  and  $0.8 \cdot L_2$ .
- [c22] The tool of claim 21, wherein each of said expansion segments has a length between about  $0.25 \cdot L_2$  and  $0.5 \cdot L_2$ .
- [c23] The tool of claim 20, wherein a first of said expansion segments of said first section has a length at least about twice the length of an average length of the other expansion segments of the first and second sections.
- [c24] A tool for radially plastically expanding a pipe having a threaded connection therein, comprising:  
a section having an increasing diameter and increasing cone angle along a direction of travel through the pipe, the section comprising an outer surface adapted to contact an inner surface of the pipe at a plurality of selected contact patches on the outer surface.
- [c25] A method of expanding casing comprising  
forcing a casing expansion tool through a casing segment axially and rotating said tool about a longitudinal axis of said tool, wherein the casing segment has a

smaller inside diameter than a largest outside diameter of said expansion tool;

wherein said expansion tool comprises a first section having an increasing diameter and increasing cone angle along a direction of travel through the casing segment, the first section comprising a first outer surface adapted to contact an inner surface of the casing segment at a plurality of selected contact patches, each contact patch comprising a plurality of ball bearings.